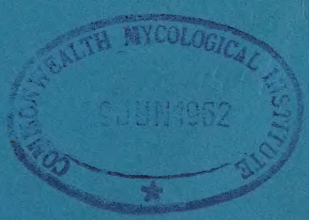
PUBLICATION 1104
JUNE 1961

DISTRIBUTION AND PERSISTENCE OF METHYL BROMIDE, ETHYLENE DIBROMIDE AND CARBON TETRACHLORIDE APPLIED IN GRAIN FUMIGANT MIXTURES

Research Branch
CANADA DEPARTMENT OF AGRICULTURE



Publication 1104 May 1961

DISTRIBUTION AND PERSISTENCE OF METHYL BROMIDE, ETHYLENE DIBROMIDE AND CARBON TETRACHLORIDE APPLIED IN GRAIN FUMIGANT MIXTURES

by

Ben Berck

Research Station, Winnipeg, Canada

RESEARCH BRANCH

CANADA DEPARTMENT OF AGRICULTURE

Copies of this publication may be obtained from:

Information Division
CANADA DEPARTMENT OF AGRICULTURE
Ottawa, Ontario

ROGER DUHAMEL, F.R.S.C.
QUEEN'S PRINTER AND CONTROLLER OF STATIONERY
OTTAWA, 1961

15C–27859–6:61

Cat. No. A53–1104

DISTRIBUTION AND PERSISTENCE OF METHYL BROMIDE, ETHYLENE DIBROMIDE AND CARBON TETRACHLORIDE APPLIED IN GRAIN FUMIGANT MIXTURES[1]

ABSTRACT

Methyl bromide (MB), ethylene dibromide (EB) and carbon tetrachloride (CT) were applied singly and in admixture to the surface of 5-foot columns of wheat of 15.8 per cent moisture content. EB applied singly was strongly sorbed at the surface of the column. MB diffused downward more rapidly and in greater concentrations. Addition of CT caused significantly greater amounts of both EB and MB to penetrate to the bottoms of the wheat columns. The fumigant concentrations found throughout the columns were in general agreement with mortalities of adults of *Tribolium confusum* Duv. That EB + CT was more effective than EB + MB as an insecticide at lower levels of the wheat column is explained partly by the improved downward distribution and persistence of EB when CT was present. When wheat and flour were exposed to EB-MB mixtures in a fumigation chamber, EB was sorbed more rapidly and to a much greater degree than MB, and the EB : MB ratios were altered appreciably. Hence, it should not be assumed that the proportions of the components of a fumigant mixture remain constant during fumigation.

INTRODUCTION

Fumigants vary not only in toxicity to insects but also in the degree to which they can penetrate to the bottom of a grain pile. This is the basis for formulating fumigant mixtures for stored grain, two or more fumigants of different penetration characteristics being combined to yield a balanced or "all-purpose" mixture capable of combating infestations at all levels. In addition, a combination of fumigants may act synergistically, to produce greater insecticidal effect.

These and other aspects of the evaluation of fumigants require knowledge of concentration-time (distribution-persistence) relationships between the fumigant and the fumigated material under given conditions and, for mixtures, whether the component gases remain in the same ratio in the presence as well as in the absence of the material (e.g., wheat or flour). A combination of chemical and bioassay methods is of value in obtaining such information.

This is a report on tests conducted with methyl bromide, ethylene dibromide and carbon tetrachloride (MB, EB and CT) applied both singly and in admixture to columns of grain simulating grain stored in elevator bins and country warehouses in Western Canada. Tests were also made with two proprietary fumigant

[1] Contribution No. 64, Research Station, Winnipeg, Manitoba.

mixtures: Dawson 73 (D.73), consisting of EB and MB in the ratio 7 : 3 by weight; and Dowfume EB-5 (EB-5), consisting of EB, ethylene dichloride (EDC) and CT in the ratio 7.2 : 29.2 : 63.6.

Columns of wheat were set up in one warehouse, known amounts of fumigants were applied singly and in admixture as liquids to the surface, and the gas-air concentration and insecticidal effectiveness of each treatment were measured at the top, middle and bottom of each column. To map the concentration-time patterns of each component, chemical methods of determining MB, EB and CT were developed (1). In addition, measurements were made to determine the effect on the composition of a vapor mixture when wheat and flour were exposed to EB-MB combinations that were applied in the vapor phase in a fumigant testing chamber (1).

METHODS

Rates of penetration and persistence of MB, EB and CT were compared in the following manner:

A series of galvanized metal cylinders, 7½ feet high and 15 inches in diameter, were set up in one warehouse at a mean temperature of 48° F. (Figure 1). Each cylinder was filled to the 5-foot level with 5 bushels of wheat (Grade 3 Northern, 15.8 per cent moisture, 8 per cent dockage). The fumigants were applied to the surfaces by removing the upper 2½-foot section of each cylinder and adding the required weight of fumigant. The upper section was then immediately replaced, providing a still air space similar to that above a pile of wheat stored in a farm granary or annex to a country elevator. All the fumigants were applied as liquids except that MB was applied as a gas. For MB, the surface of the grain was covered with polyethylene sheeting about 0.01 inch thick. A weighed glass ampoule of MB was held outside the test cylinder with the tip of the ampoule fitted into plastic tubing (Tygon, U.S. Stoneware Co., Akron 9, Ohio) that led to a 6-inch petri plate placed beneath the polyethylene sheet. The MB gas was released by breaking the tip with pliers and warming the walls of the ampoule. In a later test the required weight of MB was released from a lecture bottle placed on a trip balance.

Before the fumigants were applied, screen cages containing coarsely ground wheat and 25 adults of the confused flour beetle, *Tribolium confusum* Duv., were placed centrally at the top, middle and bottom of each cylinder. The test cages were removed for examination 3, 7 and 14 days after application of the fumigants.

As shown in Figure 1, three outlets in each cylinder permitted sampling of fumigant gas in the interstitial air at the middle and 4 inches from each end of the column of wheat. Each sampling hole was fitted with a rubber stopper pierced by a 6-mm. glass tube that extended to within 1½ inches of the center of the cylinder. A clamp on a short length of rubber tubing closed the outer end of the glass tube.

The gas-air concentrations were sampled with evacuated bottles at intervals after application of the fumigants. Milk bottles ranging in size from ½ pint

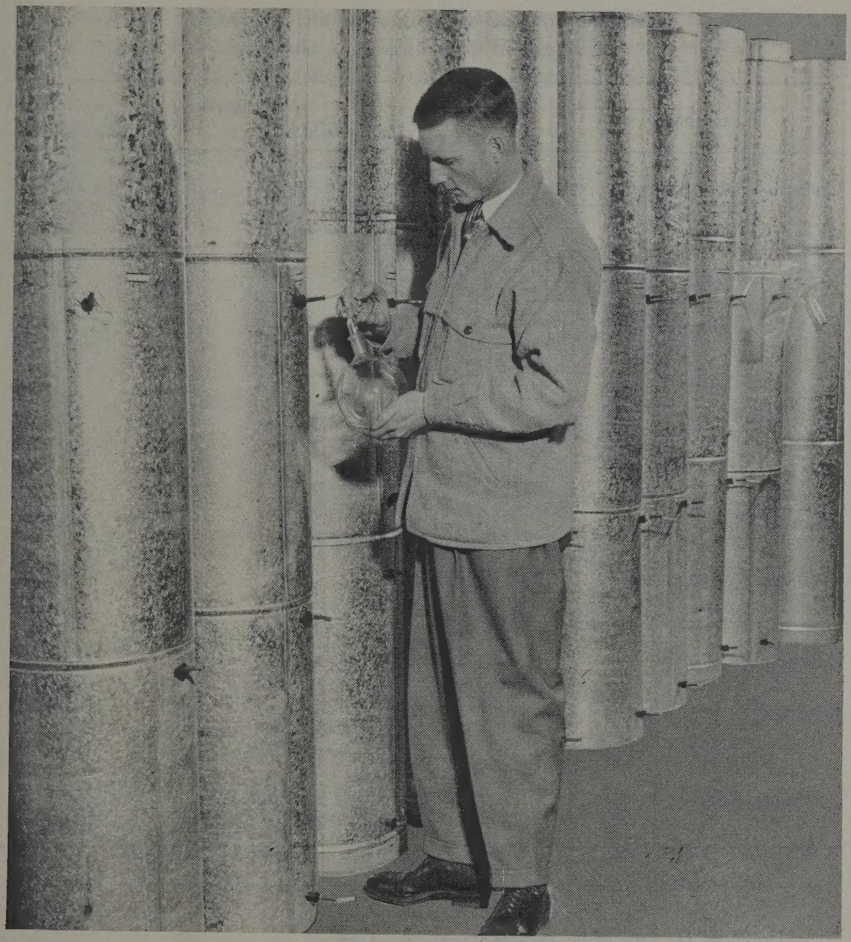


Figure 1.— A technician takes gas samples (a full-face respirator is worn in practice). Each of the 7½-foot galvanized metal cylinders contains 5 bushels of wheat and is fitted with 3 gas-sampling outlets as described in the text.

to 1 quart and containing 10 ml. of a 1 : 4 v/v mixture of monoethanolamine and n-propanol were used (1).

Temperatures before fumigation, taken by thermocouple at the centers of the test cylinders, varied from 46° to 48° F.

Table 1 shows the fumigants and the rates of application used. D.73 at 6 pounds per 1000 bushels and Dowfume EB-5 at 46.2 pounds were close to commercially recommended dosages. At these rates, the amount of EB applied was

Table 1.– Rates of application of fumigant to surfaces of 5-foot columns of wheat

Fumigant	Dosage lb. / 1000 bu.	gm. / 5 bu.
Carbon tetrachloride (CT)	32.0 (2 imp. gal.)	72.6
	64.0 (4 " ")	145.2
Methyl bromide (MB)	6.0	13.6
Ethylene dibromide (EB)	4.2	9.6
	8.4	19.1
EB + CT, 1:1, w/w	8.4	19.1
1:3, w/w	16.8	38.2
1:5, w/w	25.2	57.3
Dawson 73 (D.73)[1]	6.0	16.4
D.73 + CT, 1:1, v/v	10.8	29.5
1:3, v/v	20.4	55.7
Dawson 37 (D.37)[1]	6.0	16.4
D.37 + CT, 1:1, v/v	11.2	30.5
1:3, v/v	21.5	58.7
Dowfume EB-5[1]	23.1 (1.5 imp. gal.)	52.5
	46.2 (3 " ")	105.0

[1]Composition, w/w:–
Dawson 73: 70% EB, 30% MB; sp. gr., 2.04.
Dawson 37: 30% EB, 70% MB; sp. gr., 1.86.
Dowfume EB-5: 7.2% EB, 29.2% EDC, 63.6% CT; sp. gr., 1.54.

22 per cent greater for D.73 than for EB-5. For Dowfume EB-5, EDC was calculated as CT, since EDC could not be distinguished from CT by the methods (1) used.

To obtain data on sorption, changes in EB and MB concentrations that resulted from exposure of wheat and flour to EB-MB vapor mixtures in a steel drum (1) were measured by plotting gas concentration against time. The wheat or flour was placed in a large desiccator, with the lid of the desiccator attached to a steel wire to permit raising of the lid after the fumigant was introduced and circulated in the drum.

Table 2.– Average concentrations[1] of methyl bromide (mg./l. air) at top, middle and bottom (T, M and B) of 5-foot column of wheat at various intervals after application of fumigants to the surface

Treatment	Part of	Interval					
Amount per 1000 bu.	column	2 hr.	6 hr.	12 hr.	1 day	3 days	7 days
Dawson 73	T	0.4	0.4	0.4	0.5	1.5	1.0
6 lb.	M	2.2	1.8	2.0	2.5	1.0	0.4
	B	7.4	6.0	2.9	0.5	0.8	0.4
D.73 + CT	T	15.7	13.1	2.0	2.2	1.3	0.7
1:1 v/v	M	17.8	11.1	2.0	2.7	0.9	0.4
10.8 lb.	B	10.0	19.7	11.7	0.9	0.8	0.4
D.73 + CT	T	16.5	8.2	2.5	6.2	0.9	0.8
1:3 v/v	M	27.0	14.2	2.5	3.8	1.7	0.3
20.4 lb.	B	14.2	3.1	14.2	10.6	3.4	0.4
Dawson 37	T	3.6	2.4	2.0	3.3	1.1	0.6
6 lb.	M	11.6	11.3	7.2	4.9	1.3	0.4
	B	9.0	7.4	7.4	3.6	1.3	0.4
D.37 + CT	T	9.0	4.3	1.7	1.8	1.1	0.7
1:1 v/v	M	14.5	6.7	2.5	2.8	1.1	0.4
11.2 lb.	B	15.1	13.5	12.4	5.8	2.7	0.4
D.37 + CT	T	18.0	7.1	1.8	1.8	1.8	0.6
1:3 v/v	M	22.9	1.6	2.5	2.9	1.2	0.3
21.5 lb.	B	14.4	13.1	14.2	8.6	2.2	0.3
Methyl bromide	T	8.6	5.2	5.2	2.4	2.0	1.1
6 lb.	M	51.8	26.3	21.5	10.3	3.7	1.2
	B	28.8	22.6	17.6	14.6	3.5	1.3

[1]Duplicate tests.

RESULTS AND DISCUSSION

Distribution of Methyl Bromide

Table 2 indicates the concentration-time relationships at the top, middle and bottom of the 5-foot column of wheat to which MB and MB mixtures were applied.

Table 3.– Average concentrations[1] of ethylene dibromide (mg./l. air) at top, middle and bottom (T, M and B) of 5-foot column of wheat at various intervals after application of fumigants to the surface

Treatment	Part of	Interval					
Amount per 1000 bu.	column	2 hr.	6 hr.	12 hr.	1 day	3 days	7 days
EB	T	5.9	6.1	7.8	5.7	3.3	0.8
4.2 lb.	M	0.2	0.2	0.4	0.4	0.1	0.2
	B	0.8	0.4	0.3	0.3	0.2	0.1
EB	T	4.2	5.9	6.3	7.2	5.7	2.3
8.4 lb.	M	0.2	0.6	0.8	0.4	0.1	0.2
	B	0.2	0.8	0.9	0.3	0.1	0.1
EB + CT	T	11.3	14.0	10.8	3.3	1.4	1.8
1:1 w/w	M	10.6	7.7	8.8	7.5	2.7	1.9
8.4 lb.	B	5.0	12.5	7.0	9.2	2.5	1.4
EB + CT	T	19.5	15.0	6.5	8.6	1.0	2.0
1:3 w/w	M	19.4	24.4	16.0	7.9	3.0	2.2
16.8 lb.	B	25.4	24.8	23.2	8.0	2.6	1.8
EB + CT	T	19.2	9.4	4.9	2.5	1.1	1.2
1:5 w/w	M	26.0	24.5	25.4	10.8	3.7	2.5
25.2 lb.	B	40.5	32.7	23.4	12.4	4.0	1.4
Dawson 73	T	8.3	5.4	7.0	1.5	1.6	0.7
6 lb.	M	4.0	1.6	0.0	1.3	0.1	0.1
	B	1.8	0.3	0.3	0.3	0.0	0.0
D.73 + CT	T	14.4	5.7	4.9	6.1	0.4	0.5
1:1 v/v	M	28.0	9.5	6.5	1.3	0.6	0.5
10.8 lb.	B	26.2	6.8	4.5	0.2	0.3	0.7
D.73 + CT	T	37.2	2.5	6.1	3.1	1.1	0.5
1:3 v/v	M	33.4	2.7	6.1	2.2	0.0	0.7
20.4 lb.	B	33.2	12.6	0.5	1.0	0.1	1.3

[1]Duplicate tests.

The MB concentrations of the D.73 treatment were low, presumably because of the relatively low MB content (30 per cent MB) of the mixture. In view of its volatility, some MB has probably escaped before or during application, thus de-

Table 3.– Average concentrations[1] of ethylene dibromide (mg./l. air) at top, middle and bottom (T, M and B) of 5-foot column of wheat at various intervals after application of fumigants to the surface – concluded

Treatment	Part of	Interval					
Amount per 1000 bu.	column	2 hr.	6 hr.	12 hr.	1 day	3 days	7 days
Dawson 37	T	2.4	1.6	1.6	0.7	0.9	0.3
6 lb.	M	2.9	0.4	0.4	0.4	0.6	0.1
	B	0.5	0.7	0.2	1.4	0.2	0.2
D.37 + CT	T	17.2	2.9	3.4	0.6	0.5	0.2
1:1 v/v	M	3.2	6.3	5.9	1.3	0.2	0.5
11.2 lb.	B	19.8	8.2	2.7	0.7	0.0	0.7
D.37 + CT	T	7.2	4.2	4.2	1.1	0.0	0.1
1:3 v/v	M	33.0	2.0	5.6	0.9	0.1	0.7
21.5 lb.	B	32.1	7.4	11.2	1.2	0.6	1.3
Dowfume EB-5	T	30.1	6.0	10.0	4.9	2.0	1.0
1.5 gal.	M	38.9	24.7	12.2	9.0	6.1	1.4
	B	--	29.0	21.1	14.0	4.2	1.1
Dowfume EB-5	T	42.5	9.9	10.8	8.0	2.7	1.1
3 gal.	M	44.5	26.5	16.3	6.3	1.6	1.1
	B	48.2	21.8	23.4	11.3	6.0	1.3

[1]Duplicate tests.

creasing its availability in the column. This speculation is supported by the higher MB concentrations found after the D.37 (70 per cent MB) treatment.

Addition of CT to both D.73 and D.37 significantly assisted the penetration of MB to the bottom. This agrees with observations of Dennis and Whitney (3).

When MB was applied alone, the gas concentrations that resulted were greater, and the gas penetrated deeper and persisted longer, than when D.73 or D.37 was applied. However, apart from the larger amount of MB that was initially present, namely, 6 pounds per 1000 bushels as against 1.8 and 4.2 pounds for D.73 and D.37 respectively, the higher concentrations were probably due in part to the plastic blanket that was used when the MB was applied.

Distribution of Ethylene Dibromide

The concentration-time relationships of EB are shown in Table 3.

EB applied alone was strongly sorbed at the surface of the column, as in-

dicated by the low concentrations of EB at the middle and the bottom. The relatively greater sorption of EB by grain, especially when the moisture content is about 15 per cent, was also noted by the author in field tests and agrees with the trends noted by Olomucki and Bondi (6). Table 3 also shows that doubling the dosage (to 8.4 pounds per 1000 bushels) did not increase the downward diffusion of EB.

The combination of MB and EB in D.73 and D.37 increased the downward movement of EB only slightly. The EB-assisting effect of MB was evidently minimal.

The assisting influence of CT on the downward diffusion of EB is shown by the marked increase in EB throughout the column when CT was added to EB, D.73 or D.37. CT possibly acts here as a carrier gas, as it does in vapor phase chromatography.

The highest EB concentrations at all sampling levels were obtained with EB-5. This may be attributed to the presence of CT in the mixture, although no attempt was made to assess the role of EDC, which was also present but was measured as CT. The larger EB-air concentrations shown by EB-5 at 46.2 pounds per 1000 bushels as compared with D.73 at 6 pounds were not due to greater initial EB content, since at these rates of application the amount of EB applied to the surface of the columns was 22 per cent less with EB-5 than with D.73.

Distribution of Carbon Tetrachloride

The CT concentrations resulting from the D.73-CT mixture were significantly higher than those from the corresponding D.37-CT mixture (Table 4). The source of the difference is not evident.

The somewhat large amounts of CT gas released by the CT treatment and, to a lesser extent, by EB-5 are related to the amounts of CT in the formulations

Table 4.– Average concentrations[1] of carbon tetrachloride (mg./l. air) at top, middle and bottom (T, M and B) of 5-foot column of wheat at various intervals after application of fumigants to the surface

Treatment	Part of	Interval					
Amount per 1000 bu.	column	2 hr.	6 hr.	12 hr.	1 day	3 days	7 days
Dawson 73 + CT	T	45.0	11.7	5.0	4.5	1.9	1.8
1:1 v/v	M	11.7	8.0	4.9	1.9	1.0	0.6
10.8 lb.	B	4.8	1.8	5.7	2.3	0.8	0.7
D.73 + CT	T	53.6	9.0	6.7	3.7	1.5	1.5
1:3 v/v	M	29.6	10.1	3.7	2.9	0.7	0.8
20.4 lb.	B	34.5	17.5	6.2	2.8	1.4	1.0

[1]Duplicate tests.

Table 4.– Average concentrations[1] of carbon tetrachloride (mg./l. air) at top, middle and bottom (T, M and B) of 5-foot column of wheat at various intervals after application of fumigants to the surface – concluded

Treatment	Part of	Interval					
Amount per 1000 bu.	column	2 hr.	6 hr.	12 hr.	1 day	3 days	7 days
Dawson 37 + CT	T	3.1	3.1	2.8	1.5	1.2	2.6
1:1 v/v	M	11.2	5.3	3.1	1.5	0.7	1.1
11.2 lb.	B	8.2	23.8	3.7	1.3	0.8	1.3
D.37 + CT	T	23.5	5.6	4.0	1.5	1.4	1.9
1:3 v/v	M	13.6	2.4	3.3	1.8	0.9	1.2
21.5 lb.	B	21.0	4.1	5.5	3.4	1.7	1.2
EB + CT	T	23.4	15.0	9.9	6.9	4.0	1.8
1:1 w/w	M	16.1	18.1	10.7	6.1	3.9	1.9
8.4 lb.	B	24.2	16.0	11.3	4.9	3.9	1.4
EB + CT	T	30.0	12.6	7.0	3.3	1.9	2.0
1:3 w/w	M	38.3	18.4	8.4	6.0	1.9	2.2
16.8 lb.	B	52.2	30.0	6.2	7.5	1.5	1.8
EB + CT	T	48.4	18.1	11.3	4.2	2.0	1.2
1:5 w/w	M	32.5	20.6	14.2	4.8	5.0	2.5
25.2 lb.	B	67.6	34.8	20.6	8.0	2.2	1.4
Dowfume EB-5	T	8.9	14.7	5.6	4.2	1.9	2.5
3 gal.	M	67.2	18.0	11.0	1.9	1.0	1.5
	B	75.4	53.4	13.8	6.5	3.5	0.9
Dowfume EB-5	T	57.1	11.9	4.0	3.3	3.9	2.3
1.5 gal.	M	66.1	12.6	8.3	5.3	2.0	1.0
	B	--	21.6	9.7	4.5	1.5	0.8
CT	T	37.6	6.7	3.3	1.8	1.5	0.6
2 gal.	M	94.9	32.6	4.1	12.2	5.1	0.5
	B	156.0	58.0	47.7	14.1	7.8	0.9
CT	T	42.2	29.1	26.2	5.2	1.5	1.5
4 gal.	M	285.0	231.0	120.5	37.5	14.2	7.5
	B	390.0	321.0	219.0	85.5	28.6	5.3

[1]Duplicate tests.

Table 5.– Average mortalities (%)[1] of adults of the confused flour beetle at top, middle and bottom (T, M and B) of a column of wheat at 3 and 7 days after application of fumigants

Treatment Amount per 1000 bu.	Part of column	3 days	7 days	Treatment Amount per 1000 bu.	Part of column	3 days	7 days
Untreated	T	12	16	D.73, 6 lb.	T	100	100
	M	0	4		M	36	96
	B	4	8		B	4	16
EB, 4.2 lb.	T	96	100	D.73 + CT, 1:1 v/v	T	100	100
	M	40	80	10.8 lb.	M	72	68
	B	100	100		B	40	80
8.4 lb.	T	100	100	1:3 v/v	T	100	100
	M	4	84	20.4 lb.	M	24	68
	B	12	72		B	12	26
EB + CT, 1:1 w/w	T	100	100	D.37, 6 lb.	T	100	100
8.4 lb.	M	8	78		M	100	100
	B	36	84		B	100	100
EB + CT, 1:3 w/w	T	100	100	D.37 + CT, 1:1 v/v	T	100	100
16.8 lb.	M	32	100	11.2 lb.	M	100	100
	B	60	84		B	100	100
MB, 6 lb.	T	100	100	1:3 v/v	T	100	100
	M	100	100	21.5 lb.	M	72	100
	B	100	100		B	100	100
CT, 2 gal. (32 lb.)	T	8	28	Dowfume EB-5	T	100	100
	M	32	76	3 gal. (46.2 lb.)	M	100	100
	B	12	52		B	100	100

[1]Duplicate tests.

and to the probability that CT is not sorbed by wheat, as indicated by its ready penetration to the bottom of the column. Furthermore, doubling the dosage of CT to 4 gallons per 1000 bushels increased the CT concentration considerably.

Insecticidal Effectiveness

With some exceptions that are difficult to explain (e.g., EB at 4.2 pounds per 1000 bushels) the bioassay (Table 5) supported the previous evidence of preferential sorption of EB at the surface of a column of grain and the "takedown" or eluting effect of CT on EB. Addition of CT to D.73 increased the toxicity at the bottom of the column, although with D.37 the mortalities were 100 per cent throughout the column without the help of CT. The latter result is attributable to the greater content of MB in D.37 than in D.73 and to the greater toxicity of MB than of CT to the insects. At 25° C. for 5 hours' exposure, the median lethal concentration (LC_{50}) of MB to *T. confusum* adults has been reported as 11 mg./l. of air (7), and to *S. granarius* adults as 3.3 mg./l. (4).

The 100-per-cent mortality of *T. confusum* from EB-5 and from MB throughout the column needs no comment. CT, although present in high concentration, was much less effective and slower-acting. The latter result agrees with LC_{50} values reported by various investigators. Thus, for 5-hour exposures, the LC_{50} of CT vapor to *T. confusum* adults is 185 mg./l. air at 25° C. (7), and to *S. granarius* adults it is 275 mg./l. at 25° C. (4) and 592 mg./l. at 20° C. (2). On the other hand, LC_{50} values for EB to *T. confusum* adults, at 25° C. for 5 hours, are 3.4 (5) and 14 (9) mg./l.

Sorption of EB-MB Mixtures

The changes in the EB : MB ratio were considerable when EB-MB mixtures were applied as described (Table 6). Other tests by the author (unpublished) clearly showed that EB is sorbed mainly within the first 24 hours, and that the sorption is substantially greater when the moisture content of the wheat or flour is raised.

Table 6 demonstrates that EB : MB ratios may, as a result of the sorption of EB by the fumigated material, be substantially altered from the original proportions. Consequently, for such fumigant mixtures and possibly for others, insecticidal concepts based on chemical constancy may not apply in practice. A corollary of this finding is that claims for synergism in mixtures, as well as those for "ordinary" (i.e., nonsynergistic) mixtures, should be checked by investigating the effects of the treated material on the molecular ratios of the mixture.

Other Tests

Tests were also made on the germination, milling and baking characteristics of the treated wheat. These were conducted in Winnipeg at the Grain Research Laboratory and the Seed Branch Laboratory, Canada Department of Agriculture, and the Ogilvie Flour Mills Laboratory; and in St. Boniface, Man., at the Maple Leaf – Purity Flour Mills. The tests indicated that (a) the milling and baking qualities of the wheat were unaffected by the fumigations, (b) the treatments had no effect on the naturally occurring thiamine (Vitamin B_1) of the wheat, and (c)

Table 6.– EB : MB ratios (MB = 1.0) in air at various intervals after application of the gases to wheat and flour, each at two moisture contents, in fumigation drum

Interval days		H_2O content of wheat, % 16.7	12.0	H_2O content of flour, % 12.0	11.25
0.0		6.60	2.95	1.00	1.35
0.67		1.95	1.70	0.52	0.83
1.0		1.79	1.43	0.54	0.76
2.0		1.50	1.38	0.47	0.73
3.0		1.18	1.40	0.46	0.50
4.0		1.08	1.42	0.41	0.50
5.0		0.92	1.29	0.36	0.45
Percentage of original concentration after 5 days	EB	9.9	31.3	14.8	26.2
	MB	70.0	71.9	55.0	58.0

there was no marked difference in germination between treated and untreated samples though seedlings from lots treated with MB had slightly thickened root tips and shorter roots.

The writer also determined the total bromide residue of wheat sampled at the tops and bottoms of the test cylinders, using the method of Shrader, Beshgetoor and Stenger (8). The residues ranged from 0 to 565 ppm and varied with the kind of fumigant, the site of the sample and the period of aeration. In fumigation-drum (vapor-phase) experiments, the residues varied from 6 to 45 ppm. When the wheat and flour were relatively dry, more of the bromide was found in samples taken from the bottom of the desiccator, whereas when the wheat and flour were comparatively moist more of the bromide was found in samples taken from the top and middle areas. Also, the residues were largely volatile, since they diminished considerably upon aeration.

ACKNOWLEDGMENTS

Grateful acknowledgment is given for the co-operation of the following firms and government departments: Grain Research Laboratory, Board of Grain Commissioners for Canada, Winnipeg, for milling and baking tests; Maple Leaf – Purity Flour Mills, St. Boniface, Man., for determinations of ash content of treated flour

and wheat; Ogilvie Flour Mills, Winnipeg, for ashing of many samples of given fractions of milled wheat; and the Seed Branch Laboratory, Canada Department of Agriculture, Winnipeg, for germination tests.

REFERENCES

1. Berck, B. Determination of methyl bromide, ethylene dibromide and carbon tetrachloride in admixture in air. Canada Dept. Agr. Pub. 1101. 1961.
2. Busvine, J. R. Relative toxicity of insecticides. Nature 150 : 208-209. 1942.
3. Dennis, N. M., and W. K. Whitney. The effect of varying the volatilization of methyl bromide by combinations with various solvents in its distribution in bulk grain fumigation. U.S. Dept. Agr. Bull. AMS-73 : 1-18. 1955.
4. Ferguson, J., and H. Pirie. Toxicity of vapors to the grain weevil. Ann. Appl. Biol. 35 : 532-550. 1948.
5. Lindgren, D. L., L. E. Vincent and H. E. Krohne. Relative effectiveness of ten fumigants to adults of eight species of stored-product insects. J. Econ. Ent. 47 : 923-926. 1954.
6. Olomucki, E., and A. Bondi. Ethylene dibromide fumigation of cereals. I. Sorption of ethylene dibromide by grain. J. Sci. Food Agr. 6 : 592-600. 1955.
7. Shepard, H. H., D. L. Lindgren and F. L. Thomas. Relative toxicities of insect fumigants. Minn. Agr. Expt. Sta. Tech. Bull. 120 : 3-23. 1937.
8. Shrader, S. A., A. W. Beshgetoor and V. A. Stenger. Determination of total and inorganic bromide in foods fumigated with methyl bromide. Ind. Eng. Chem., Anal. Ed. 14 : 1-4. 1942.
9. Young, H. D., and R. T. Cotton. Certain organic bromides as grain fumigants. J. Econ. Ent. 36 : 796-797. 1943.